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PHYSIOLOGICAL RESPONSES TO UNVARYING (STEADY) AND 2-2-1 SHIFTS: MIAMI INTERNATIONAL FLIGHT SERVICE STATION

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16. Abstract

Two types of shift rotation in the same air traffic facility were investigated in order to determine the relative advantages and disadvantages of nonrotating shift work (steady shift) and rotating shift work. The rotating shift work chosen for comparison was a 2-2-1 pattern often preferred by air traffic controllers, and which consists of a schedule of progressively earlier work periods throughout the workweek, with 9 to 14 hours off duty between 8-hour work periods, and an extended off-duty period of 80 hours between workweeks.

Objective differences, as judged by urine biochemistry, between workers on the two shift patterns are minimal and insignificant statistically. Generally, however, greater fatigue was reported in connection with the 2-2-1 rotation than with the steady shift, both preshift and postshift. When prework to postwork changes in subjective fatigue were compared for the two shift patterns, no statistically significant differences were noted.

Within the 2-2-1 schedule, there was (i) significantly greater excretion of catecholamines on the day watch as compared to the evening watch; and (ii) significantly greater preshift fatigue reported on day shift than evening shift.

Despite the observed differences between and within the steady and rotating shift patterns, employee participation in shift pattern choice may have contributed greatly to worker contentment and willingness to accept the observed stressors. Keywords:

A separate addendum clarifies specific biochemical data interpretation difficulties encountered in this study.

17. Key Words

Shift Work, Air Traffic Controllers, Biochemistry, Fatigue, Employee Participation.

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INTRODUCTION

Previous work in this laboratory has shown that the 2-2-1 shift rotation pattern in common use in air traffic facilities was less stressful than was the "straight five" rotation pattern (4,6). The 2-2-1 consists of a schedule of progressively earlier work periods throughout the workweek with 9 to 14 hours off duty (quick turnarounds) between 8-hour work episodes. The "straight five" shift rotation schedule calls for weekly changes of work hours; on this schedule an air traffic control specialist (ATCS) works 5 straight days on the same watch and has 16 hours off duty between 8-hour work episodes.

The ATCS's generally prefer the 2-2-1 rotation because of the extended off-duty period (80 hours) between workweeks. Management's attitude toward the 2-2-1 is best described as reluctant tolerance, believing that the quick turnarounds do not allow time for adequate rest between watches. However, there is demonstrably less physiological stress associated with the 2-2-1 than there is with the "straight five" schedule because the ATCS preference increases job satisfaction and there is less circadian disruption since ATCS's effectively work days and sleep at night except for the lone midwatch on the last day of the workweek.

The earlier research referenced above points out that five consecutive midwatches on the "straight five" rotation is the most stressful event related to ATC rotating shift work; 5 days is not long enough for circadian re-entrainment to occur and thus allows accumulation of fatigue associated with inadequate daytime sleep.

It has been argued by Czeisler et al. (2) that the direction of shift change is as important as is the pattern of rotation. This contention is based on the observation that the diurnal wake/sleep cycle (biological day) is longer than the 24-h solar day in contrived experimental environments devoid of time cues. Rotating schedules that involve progressively earlier watches, as does the classic 2-2-1 pattern, are called "advancing" schedules; those that involve progressively later watches are called "delayed" schedules. Delayed schedules work in the same direction as the biological day and, therefore, are apparently less stressful than are advancing schedules. For the same reason, east-to-west flight (delayed schedule) across several time zones is less disruptive biologically than is west-to-east flight (advancing schedule).

Nonrotating shift work (steady shift) is an obvious remedy to circadian disruption associated with rotating shift work. However, in air traffic control (ATC) work, several objections to steady shifts, all related to the midwatch, have been raised: (i) traffic is characteristically light on the midwatch, thus causing deterioration of proficiency in handling heavier daytime workload should the ATCS be called on to do such work; (ii) difficulties in making weekend and vacation adjustments to daytime

activities and night sleep; (iii) social isolation from professional colleagues and difficulties in attending daytime briefings and conferences; and (iv) family problems related to the ATCS's working period being out of synchrony with wife's and/or children's activities.

Surprisingly, no published work has been found that compares stress of rotating shifts with steady shifts in the same work setting. Therefore, when we learned that the 2-2-1 and the steady shifts were both in use at the Miami International Flight Service Station (MIA IFSS) we immediately set procedures in motion to carry out a study at that facility aimed at comparing physiological stress in ATCS's on the two work schedules. Further, employees at the MIA IFSS could bid on work periods; many could consequently arrange for regular off-duty activities.

The field phase of the study was carried out in late November and early December 1982.

METHODS

Thirty-seven workers at the MIA IFSS volunteered to serve as subjects in the study (Table I). The average age of the subjects was 42.6 years (range 24-62); the median age was 43 years.

Subjects were fully informed about the procedures and purposes of the project; each signed an informed consent document prior to his/her participation.

Each subject collected two pooled urine specimens for each day of participation representing his/her sleep period and work period. Acidified specimens were frozen at the work site and remained frozen until they were analyzed at the Civil Aeromedical Institute in Oklahoma City for 17-ketogenic steroids (KGS), epinephrine (E), norepinephrine (NE) and creatinine (CR); methods for these analyses have been previously published; values for these urinary metabolites are expressed as weight/100 mg CR.

Thirty minutes prior to entering on duty, ATCS's reported to the temporary laboratory where they turned in their rest period urine specimens, completed preshift questionnaires regarding medication usage and physical complaints, sleep reports, and subjective fatigue checklists (FCL). Subjects were then fitted with chest electrodes for ambulatory electrocardiography (ECG), using Avionics Electrocardiocorders, and were issued fresh urine collection vessels. At the end of the work period, subjects completed a postshift questionnaire and another FCL; the ECG electrodes were removed and a fresh vessel was issued for collection of the next rest period specimens. Recorder malfunctions not recognizable at the data collection site rendered most ECG tapes unusable; only 23 valid ECG tape recordings were collected, hardly a sufficient number for conclusive data. Heart rate values are, therefore, not reported.

There were 16 subjects on the 2-2-1 schedule and 20 subjects on the steady schedule completing all FCL's.

RESULTS

Fatigue Checklist:

The FCL data are presented in Tables II-VI. The review of the tables shows there is significantly more subjective fatigue in the 2-2-1 group than in the steady shift group when reporting for duty (preshift assessment). There was no significantly different preshift level of subjective fatigue between the steady day shift workers and the steady evening shift workers. There was an insufficient number of steady midshift workers for comparison. As a group, workers on the 2-2-1 rotation were significantly more fatigued by 8 hours of work than were steady shift workers. In some cases, postshift fatigue was classified as severe (score< 8) by 2-2-1 workers whereas no case of severe fatigue was reported by steady shift workers. Subjective postshift fatigue reported by workers on the 2-2-1 rotation was greater but not significantly so than that reported by workers on the steady evening rotation.

With regard to fatigue on the three watches of the 2-2-1 rotation, there was a statistically significantly higher level of fatigue reported prior to work on the day watch than on the evening watch (Table IV); such prework fatigue differences as existed between the day and midwatches, and the evening and midwatches were not statistically significant. In a few cases, particularly prior to the 2-2-1 midwatch, prework fatigue was reported to be severe. There was not a significant difference in fatigue levels after work on the 2-2-1 day and evening watches. However, the midshift on the 2-2-1 caused significantly more fatigue than did the day and evening watches with severe fatigue after the midwatch in all but one case (Table V). When prework to postwork changes in subjective fatigue were compared for the two shift patterns, no statistically significant differences were noted (Table VI). The predominant change was in the direction of increased fatigue reported in the postwork FCL; however, on a few occasions the postwork FCL indicated a decrease in fatigue (Table VI).

Sleep:

The average amount of sleep obtained by subjects on the two work schedules for each day of their workweek showed clearly that the most sleep was obtained prior to the first workday--8.3 h in both cases. On the 2-2-1 rotation, the amount of sleep prior to work declined almost linearly over the workweek to 5.4 h prior to the midwatch on the 5th day. On the steady shift pattern, the amount of sleep declined from 8.3 h on day 1 to 6.8-6.9 h on days 2, 3, and 4 and to 6.2 h on day 5. The average amount of sleep obtained over the 5-day workweek on the 2-2-1 schedule was 6.8 h and on the steady schedule, 7.0 h. Both the day and evening watches on the steady schedule showed a decline in the amount of sleep per night over the workweek.

Urine Biochemistry:

Statistical comparisons of ketogenic steroids (KGS) excretion levels during

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the off-duty and on-duty periods for the two work schedules showed no significant differences. That is, prework as well as postwork stress levels as indicated by adrenal steroid excretion were about the same for workers on the two schedules (Tables VII & VIII). Comparison of KGS excretion in connection with the day, evening, and midwatches of the 2-2-1 schedule likewise showed no statistically significant differences (Tables IX-X).

There were likewise no statistically significant differences in epinephrine excretion by subjects on the two work schedules (Tables XI-XII). However, epinephrine excretion was significantly greater ($p< 0.003$) on the day watch than on the evening watch of the 2-2-1 schedule (Tables XIII-XIV).

The profile of norepinephrine (NE) excretion was identical with that of epinephrine; i.e., there were no points of statistically significant difference between the two work schedules (Tables XV-XVI). However, as with epinephrine there was significantly greater ($p< 0.01$) excretion of norepinephrine in connection with day work than with evening work on the 2-2-1 schedule (Tables XVII-XVIII).

In 1974 a stress index was formulated in this laboratory based on excretion levels of the stress indicator hormones (SIH's) in urine (KGS, E, and NE). This index facilitated comparison of stress at various ATC facilities (5,7). Basically, the index consists of the product of resting and working values of each SIH mathematically treated so as to provide a unitary common denominator for each SIH. The SIH's are treated in this way so that each will have equal importance in stress assessment; otherwise, the catecholamines' importance would be overwhelmed by the steroids' importance because of the far greater amount of steroid material in urine compared to catecholamines. The individual indices are designated cst (KGS), ce (E) and cne (NE). The average of the three indices is designated Cs, the composite stress index.

When stress indices for all ATC facilities studied are listed (Table XIX), MIA IFSS tops the list as the most stressful (Cs=2.60). Individual indices for KGS and E are high at MIA IFSS although not the highest on the list. O'Hare Air Traffic Control Tower (ATCT) and Houston ATCT (1970) have higher cst values; Los Angeles and Oakland TRACON's (1974) have higher ce values. The high Cs value at MIA IFSS is mainly due to the inordinately high excretion rate of NE reflected in the cne of 5.85, about 5 to 10 times higher than other similar facilities (Table XX).

It was thought that perhaps the high level of excretion of NE might be a reflection of the age of the subjects. However, the correlation between NE excretion level and age is not statistically significant ($r=0.29$, $p> 0.30$). Some of the subjects were on medication for control of blood pressure; however, there was no apparent significant correlation between medication usage and NE excretion. Analytical reruns and audits of laboratory procedures have likewise failed to reveal experimental error as the cause of the high values. Further, urine collection procedures were identical to procedures used in other studies. The same personnel performed these analyses by the same methods as in the previous studies.

DISCUSSION

Objective differences, as judged by urine biochemistry, between workers on the two shift patterns are minimal and insignificant statistically. However, urinary excretion levels of adrenal steroids and catecholamines at MIA IFSS are so high as to raise doubts about the validity of the analyses. As yet, a technical reason for the high values has not been found. A diligent search for experimental error has delayed this report beyond the reporting time normally required for studies of this type and the search will continue as long as personnel and facilities are available for this purpose or until the validity of the high values is established. The statement above regarding minimal differences between the two shift patterns is based on the assumption that the cause(s) of the high SIH values, be it/they real or erroneous, affects all analyses equally.

Extensive experience gained through studies in ATC facilities has imparted some "feel" for the presence of high levels of stress. This "feel" is roughly equivalent to clinical impression and is based on complaints of fatigue out of proportion to effort, expressed dissatisfactions, subclinical illness, sleep problems, contentiousness, irritability, lecturing, speech making and focusing of blame on management. None, or only insignificant amounts, of these negative elements were apparent to the investigators of MIA IFSS. Contrarily, the employees who served as subjects were friendly, cooperative, interested, hospitable, complimentary about management and seemed generally satisfied. The reported amounts and quality of sleep were normal and in line with the quantity of sleep reported for other industrial workers (1).

While there were no points of statistically significant difference in SIH's between the two groups, there was a significantly greater excretion of catecholamines on the day watch as compared to the evening watch on the 2-2-1 schedule. Though we have no data to support the statement it is possible that there was a greater workload on the day shift that would cause a proportionally greater excretion of catecholamines. Earlier work in this laboratory has shown a direct and highly significant relationship between catecholamine excretion and acute workload in tower controllers (5).

With regard to subjective fatigue there are several points of statistically significant difference that are interpreted to be revealing of employee attitudes toward their work. Generally, greater fatigue was reported both preshift and postshift in connection with the 2-2-1 rotation than with the steady shift. Preshift differences were significant for days and evenings; there were too few steady midshift subjects for comparison.

Comparisons within the 2-2-1 shift group showed that day shift workers reported significantly greater fatigue than did evening shift workers. There was significantly greater fatigue reported in connection with the midshift than with the day and evening shifts. Severe fatigue was reported frequently after the midshift.

Uniformly (six exceptions), greater fatigue was reported after work than before. However, prework to postwork differences were not significant for the two shift schedules.

In the conduct of this study many opportunities were afforded to engage in conversational interviews with the subjects. A rather uniform set of reasons was given for selecting one work pattern over the other. Reasons given were not related to the work itself. It was revealed that most people who chose the steady shift did so in order to get a regular and predictable off duty period. People who worked the 2-2-1 pattern said that the extended off duty period at the end of the workweek was their motivation for that choice. Some people on both schedules said that they wanted to stay with their accustomed teams.

These personal and social factors illuminate certain human relations considerations not usually addressed. The common practice is to assign people to a schedule of work because of needs of the work place or employer. Actually, it appears that salaried people who work for a living, as opposed to creative workers such as artists who do not clearly separate vocation and avocation, do so in order to enrich their off duty lives with the compensation that they receive. Compensation always includes monetary remuneration but may, and usually does, encompass more than that, including such things as optimum time off duty when workers can enrich their lives with the money received.

It has been pointed out that control over work is an important element in job satisfaction. A fixed, unalterable, and ordained work schedule represents an out-of-control element for most workers. Thus, efforts to improve worker attitudes that are focused exclusively on environmental or "hygiene" factors in the workplace may be misdirected. Workers may choose onerous work schedules in order to get preferred or extended time off. Surveys of ATCS preference for work schedules show that the 2-2-1 rotation is preferred over the "straight five" shift pattern. This choice of the compressed schedule is based on a desire to get the 40-h workweek over with quickly (88 h) in order to have 80 consecutive hours off duty (48 percent of the 7-d week). A reversed or expanded 2-2-1 would be an apparently easier schedule of work by spreading 40 h of work over 120 h, thus providing 18-22 h between 8-h work episodes instead of the 9-14 h on the compressed 2-2-1.

A reversed 2-2-1 would, of course, allow only a 48-h weekend which would yield 32 h for waking activities, assuming two 8-h sleep periods. It is probably significant that such an "easy" schedule is not in use at any known ATC facility. The "straight five" rotation pattern provides 64-80 h between work weeks, depending on specific shift changes involved, but still second best to the compressed 2-2-1.

It is important to note that, in general, the amount and quality of work to be done is the same for all shift rotation patterns. All employees work a basic 40-h week. The various shift rotation patterns only affect the distribution of work throughout the 168 h, 7-d week, and thus affect the distribution of time off. At one ATC facility that we studied, the "straight

five" shift pattern was arbitrarily imposed in place of the established 2-2-1; a sick-out ensued and labor-management tension persisted until the 2-2-1 was restored. It is a serious mistake to think that the distribution of time off is a matter of indifference to employees. Succinctly put, it can be said that, given the opportunity, employees will choose an off duty time and accept whatever work schedule is necessary to provide that choice.

This opinion is borne out, to some degree at least, by the findings of this study. The MIA IFSS employees as a group possibly show the highest level of acute workload stress of any ATC facility yet studied. The 2-2-1 workers report severe fatigue in some cases. Yet these workers are apparently contented and willing to accept such stressors. An observer cannot help but attribute these workers' attitudes to participative management that gives employees maximum control over their time consistent with operational imperatives.

NOTE: The reader is asked to review the Addendum on pages 29 and 30.

TABLE I

SUBJECT CLASSIFICATION

SHIFT	TOTAL NUMBER SUBJECTS	NUMBER JOURNEYMEN	NUMBER DEVELOPMENTALS	NUMBER SUPERVISORS	NUMBER TELETYPE OPERATORS	NUMBER WOMEN	NUMBER MEN
2-2-1	17	14	1	1	1	3	14
STEADY	20	16	0	2	2	2	18

TABLE II

FCL COMPARISON OF PRESHIFT VALUES ON THE TWO SHIFT SCHEDULES

	2-2-1	STEADY DAYS	2-2-1	STEADY EVENING	STEADY DAYS	STEADY EVENING
	10.2	11.2	10.2	14.4	11.2	14.4
	9.0	14.6	9.0	11.8	14.6	11.8
	8.6	13.4	8.6	12.6	13.4	12.6
	11.6	12.0	11.6	9.8	12.0	9.8
	9.6	13.0	9.6	13.6	13.0	13.6
	10.0	13.0	10.0	10.4	13.0	10.4
	13.8	12.6	13.8	11.6	12.6	11.6
	9.0	13.0	9.0	11.8	13.0	11.8
	11.6	12.2	11.6	15.2	12.2	15.2
	10.8	11.6	10.8	11.6	11.6	11.6
	12.8		12.8			
	9.2		9.2			
	14.4		14.4			
	8.8		8.8			
	6.4		6.4			
	9.2		9.2			
$\bar{X}$	10.3	12.7	10.3	12.3	12.7	12.3
p(t)	.0003		.02		.55	

Note: In all tables, Student's t test has been used to determine statistical significance.

TABLE III

FCL COMPARISON OF POSTSHIFT VALUES ON THE TWO SHIFT SCHEDULES

	2-2-1	STEADY DAYS	2-2-1	STEADY EVENING	STEADY DAYS	STEADY EVENING
	7.8	10.0	7.8	14.0	10.0	14.0
	8.6	8.8	8.6	8.8	8.8	8.8
	7.8	15.2	7.8	11.2	15.2	11.2
	11.4	10.4	11.4	9.4	10.4	9.4
	8.2	8.4	8.2	6.0	8.4	6.0
	8.4	10.2	8.4	9.2	10.2	9.2
	9.6	10.4	9.6	10.0	10.4	10.0
	5.8	9.8	5.8	9.0	9.8	9.0
	10.0	11.6	10.0	11.4	11.6	11.4
	11.2	11.4	11.2		11.4	
	11.4		11.4			
	3.6		3.6			
	11.3		11.3			
	8.2		8.2			
	6.4		6.4			
	6.8		6.8			
$\bar{X}$	8.5	10.6	8.5	10.1	10.6	10.1
p(t)	.02		.08		.61	

TABLE IV

FCL COMPARISON OF 2-2-1 WATCHES - PRESHIFT

	DAY	EVENING	DAY	MID	EVENING	MID
	8.0	12.0	8.0	11.0	12.0	11.0
	8.0	10.5	9.5	7.0	8.5	7.0
	9.5	8.5	4.0	12.0	10.7	12.0
	12.3	9.0	10.0	10.0	10.0	10.0
	4.0	10.7	7.5	5.0	12.5	5.0
	10.0	10.0	10.3	10.0	17.0	10.0
	11.7	17.0	14.5	13.0	8.0	13.0
	7.5	12.5	8.5	5.0	12.0	5.0
	10.3	17.0	14.5	13.0	15.0	13.0
	9.5	16.0	2.0	7.0	10.5	7.0
	14.5	8.0	8.3	8.0	13.0	8.0
	8.5	12.0				
	14.5	15.0				
	9.0	13.0				
	2.0	10.5				
	8.3	13.0				
$\bar{X}$	9.2	12.2	8.8	9.2	11.7	9.2
S.E.	.8155	.7197	1.1328	.8926	.8022	.8926
p(t)	.01		.75		.06	

TABLE V

FCL COMPARISON OF 2-2-1 WATCHES - POSTSHIFT

	DAY	EVENING	DAY	MID	EVENING	MID
	7.0	9.0	7.0	7.0	9.0	7.0
	8.3	9.0	8.0	5.0	9.0	5.0
	8.0	9.0	10.0	4.0	9.0	4.0
	12.0	9.0	9.0	6.0	9.0	6.0
	10.0	9.0	10.5	3.0	7.5	3.0
	9.0	9.0	12.0	4.0	10.0	4.0
	9.3	10.0	12.0	12.0	9.0	12.0
	10.5	7.5	1.5	8.0	3.5	8.0
	12.0	10.0	11.5	8.0	14.0	8.0
	11.3	11.0	7.0	3.0	7.5	3.0
	12.0	9.0	6.3	3.0	12.0	3.0
	11.5	3.5				
	1.5	14.0				
	8.7	10.0				
	7.0	7.5				
	6.3	12.0				
$\bar{X}$	9.0	9.3	8.6	5.7	9.0	5.7
S.E.	.6910	.5571	.9453	.8538	.7962	.8538
p(t)	.67		.04		.02	

TABLE VI

FCL PRESHIFT-POSTSHIFT DIFFERENCES FOR THE TWO SCHEDULES*

	2-2-1	STEADY DAYS	2-2-1	STEADY EVENING	STEADY DAYS	STEADY EVENING
	2.4	1.2	2.4	0.4	1.2	0.4
	0.4	5.8	0.4	3.0	5.8	3.0
	0.8	-1.8	0.8	1.4	-1.8	1.4
	0.2	1.6	0.2	0.4	1.6	0.4
	1.4	4.6	1.4	7.6	4.6	7.6
	1.6	2.8	1.6	1.2	2.8	1.2
	4.2	2.2	4.2	1.6	2.2	1.6
	3.2	3.2	3.2	2.8	3.2	2.8
	1.6	0.6	1.6	3.8	0.6	3.8
	-0.4	0.2	-0.4	-0.8	0.2	-0.8
	1.4		1.4			
	5.6		5.6			
	3.1		3.1			
	0.6		0.6			
	0.0		0.0			
	2.4		2.4			
$\bar{X}$	1.78	2.04	1.78	2.14	2.04	2.14
p(t)	.73		.65		.92	

* NEGATIVE VALUE MEANS THAT THE POSTSHIFT SCORE WAS GREATER THAN THE PRESHIFT VALUE.

TABLE VII

KGS PRE COMPARISONS: 2-2-1 VS. STEADY PRE

	2-2-1 DAYS PRE VS. STEADY DAYS PRE		2-2-1 EVENING PRE VS. STEADY EVENING PRE	
	891.35	2383.10	665.90	735.33
	1005.87	873.50	831.25	673.57
	572.95	801.40	739.50	851.00
	700.80	372.86	1625.40	1032.87
	561.83	850.10	898.90	1003.63
	407.00	745.12	442.35	1196.78
	462.10	859.20	897.35	616.45
	905.00	923.90	378.03	864.15
	361.00	526.48	693.60	
	630.50	266.55	809.40	
	1576.50	166.00	166.00	
	2329.70	1881.50	1881.50	
	992.05	1536.10	1536.10	
	667.60		360.95	
	719.30		252.90	
	307.40		697.50	
	470.45		563.47	
	205.13		634.35	
			250.70	
$\bar{X}$	764.807	860.221	753.955	871.723
p(t)	.654		.505	

TABLE VIII

KGS POST COMPARISONS: 2-2-1 VS. STEADY POST

	2-2-1 DAYS POST VS. STEADY DAYS POST		2-2-1 EVENING POST VS. STEADY EVENING POST	
	699.30	685.00	728.40	888.10
	1427.20	707.90	1188.90	535.23
	1030.75	1147.10	1119.20	963.35
	1924.90	571.62	2008.50	830.27
	1792.98	1638.70	1026.60	1180.33
	1110.90	719.86	1174.50	1387.03
	2362.80	1099.96	740.30	1096.30
	809.15	1328.20	604.23	1208.00
	990.00	943.60	957.50	
	1460.80	625.80	1462.50	
	1304.40	486.00		
	896.55	1550.05		
	1159.95	1357.60		
	898.07	444.90		
	1324.25	857.70		
	701.25	559.60		
	816.10	654.63		
	399.77	653.70		
		380.90		
$\bar{X}$	1172.779	946.774	945.037	1011.155
p(t)	.210		.694	

TABLE IX

KGS PRE COMPARISONS: 2-2-1 PRE

	2-2-1 DAY PRE	2-2-1 EVE PRE	2-2-1 DAY PRE	2-2-1 MID PRE	2-2-1 EVE PRE	2-2-1 MID PRE
	891.35	665.90	891.35	1170.70	665.90	1170.70
	1005.87	831.25	700.80	223.50	1625.40	223.50
	572.95	739.50	462.10	638.80	897.35	638.80
	700.80	1625.40	905.00	1032.10	693.60	1032.10
	561.83	898.90	361.00	1021.50	809.40	1021.50
	407.00	642.35	1576.50	707.10	1881.50	707.10
	462.10	897.35	2329.70	1605.80	1536.10	1605.80
	905.00	693.60	667.60	626.10	252.90	626.10
	361.00	809.40				
	630.50	166.00				
	1576.50	1881.50				
	2329.70	1536.10				
	992.05	360.95				
	667.60	252.90				
	719.30	697.50				
	307.40	563.47				
	470.45	634.35				
	205.13	250.70				
$\bar{X}$	764.81	753.73	986.76	878.20	1045.27	878.20
S.E.	119.32	117.73	232.13	148.68	200.43	148.68
p(t)	.915		.582		.539	

TABLE X

KGS PRE COMPARISONS: 2-2-1 PRE

	2-2-1 DAY PRE	2-2-1 EVE PRE	2-2-1 DAY PRE	2-2-1 MID PRE	2-2-1 EVE PRE	2-2-1 MID PRE
	699.30	728.40	699.30	458.90	728.40	458.90
	1427.20	1188.90	1924.90	701.30	2008.50	701.30
	1030.75	1119.20	2362.80	310.20	740.30	310.20
	1924.90	2008.50	809.15	386.20	957.50	386.20
	1792.98	1026.60	990.90	1112.10	1462.50	1112.10
	1110.90	1174.50	1304.40	700.70	1550.05	700.70
	2362.80	740.30	896.55	948.80	1357.60	948.80
	809.15	957.50	898.07	1725.00	857.70	1725.00
	990.90	1462.50				
	1460.80	486.00				
	1304.40	1550.05				
	896.55	1357.60				
	1159.95	444.90				
	898.07	857.70				
	1324.25	559.60				
	701.25	654.63				
	816.10	653.70				
	399.77	380.90				
$\bar{X}$	1172.78	963.97	1234.76	792.90	1207.82	792.90
S.E.	115.29	103.39	211.66	164.85	162.52	164.85
p(t)	.124		.198		.100	

TABLE XI

EPI PRE COMPARISONS: 2-2-1 VS. STEADY

	2-2-1 DAYS PRE VS. STEADY DAYS PRE		2-2-1 EVENING PRE VS. STEADY EVENING PRE	
	.48	1.56	.26	.40
	1.81	.90	.53	.65
	1.05	.51	.99	.96
	.24	.32	1.43	.81
	.30	.64	.76	1.03
	.65	.83	.68	.83
	1.54	.92	1.21	.40
	.89	2.58	.61	.95
	.63	.37	.40	
	1.48	.35	1.23	
	.50		.61	
	.96		2.44	
	.92		.99	
	.79		1.26	
	.95		1.34	
	.28		.28	
	.26		.54	
	.51		1.03	
	.30		.29	
$\bar{X}$	.765	.898	.888	.754
p(t)	.544		.504	

TABLE XII

EPI POST COMPARISONS: 2-2-1 VS. STEADY

	2-2-1 DAYS POST VS. STEADY DAYS POST		2-2-1 EVENING POST VS. STEADY EVENING POST	
	.63	1.59	.50	.70
	3.01	.91	2.49	.27
	2.00	.96	1.04	3.53
	3.49	1.08	2.16	1.15
	1.88	1.33	1.86	.80
	2.79	1.50	1.77	1.42
	2.27	2.44	1.35	1.10
	.93	4.41	.82	2.15
	.41	1.66	.63	
	6.65	.54	1.83	
	2.79		1.07	
	2.60		.66	
	1.45		.83	
	1.49		.48	
	2.31		1.36	
	1.06		.81	
	.77		.96	
	1.09		1.09	
	2.18		1.59	
$\bar{X}$	2.095	1.642	1.226	1.390
p(t)	.387		.602	

TABLE XIII

EPI PRE COMPARISONS: 2-2-1

	2-2-1 DAY PRE	2-2-1 EVE PRE	2-2-1 DAY PRE	2-2-1 MID PRE	2-2-1 EVE PRE	2-2-1 MID PRE
	.48	.26	.48	.51	.26	.51
	1.81	.53	1.05	1.05	.99	1.05
	1.05	.99	.24	.46	1.43	.46
	.24	1.43	1.54	2.89	1.21	2.89
	.30	.76	.63	.82	.40	.82
	.65	.68	1.48	2.35	1.23	2.35
	1.54	1.21	.50	.37	.61	.37
	.89	.61	.96	.50	2.44	.50
	.63	.40	.92	1.53	.99	1.53
	1.48	1.23	.95	.94	1.34	.94
	.50	.61	.30	.69	.29	.69
	.96	2.44				
	.92	.99				
	.79	1.26				
	.95	1.34				
	.28	.28				
	.26	.54				
	.51	1.03				
	.30	.29				
$\bar{X}$	.765	.888	.823	1.101	1.017	1.101
S.E.	.106	.123	.132	.250	.191	.250
p(t)	.375		.099		.783	

TABLE XIV

EPI POST COMPARISONS: 2-2-1

	2-2-1 DAY POST	2-2-1 EVE POST	2-2-1 DAY POST	2-2-1 MID POST	2-2-1 EVE POST	2-2-1 MID POST
	.63	.50	.63	.19	.50	.19
	3.01	2.49	2.00	.66	1.04	.66
	2.00	1.04	3.49	3.19	2.16	3.19
	3.49	2.16	2.27	.32	1.35	.32
	1.88	1.86	.41	.60	.63	.60
	2.79	1.77	6.65	1.50	1.83	1.50
	2.27	1.35	2.79	1.25	1.07	1.25
	.93	.82	2.60	1.23	.66	1.23
	.41	.63	1.45	2.04	.83	2.04
	6.65	1.83	2.31	7.41	1.36	7.41
	2.79	1.07	2.18	4.01	1.59	4.01
	2.60	.66				
	1.45	.83				
	1.49	.48				
	2.31	1.36				
	1.06	.81				
	.77	.96				
	1.09	1.09				
	2.18	1.59				
$\bar{X}$	2.095	1.226	2.435	2.036	1.184	2.064
S.E.	.324	.134	.501	.647	.160	.647
p(t)	.004		.647		.181	

TABLE XV

NOREPI PRE COMPARISONS: 2-2-1 VS. STEADY

	2-2-1 DAYS PRE VS. STEADY DAYS PRE		2-2-1 EVENING PRE VS. STEADY EVENING PRE	
	4.58	13.46	3.07	5.19
	9.64	7.27	8.90	5.92
	5.51	3.03	11.64	9.01
	6.01	3.03	15.76	8.87
	3.71	10.10	5.65	9.90
	6.69	5.44	8.17	4.30
	10.46	9.22	6.59	3.50
	7.56	18.72	5.84	7.87
	5.11	5.30	3.48	
	11.60	2.77	6.69	
	5.68	4.61	10.24	
	7.53	12.87	14.10	
	8.76	5.12	2.63	
	6.38		6.16	
	6.97		6.22	
	2.57		2.81	
	2.44			
	3.90			
	2.27			
$\bar{X}$	6.177	7.[illegible]34	7.397	6.820
p(t)	.262		.703	

TABLE XVI

NOREPI POST COMPARISONS: 2-2-1 VS. STEADY

	2-2-1 DAYS POST VS. STEADY DAYS POST		2-2-1 EVENING POST VS. STEADY EVENING POST	
	4.09	11.11	2.84	5.96
	26.38	5.67	12.47	4.41
	15.71	6.08	7.58	20.58
	14.19	5.90	14.38	6.13
	7.81	13.52	5.84	4.35
	15.19	7.89	10.15	25.71
	8.58	12.85	5.42	7.13
	6.20	23.79	4.49	10.97
	3.93	11.03	4.47	
	47.07	3.60	9.79	
	13.80		7.40	
	10.35		4.62	
	10.11		7.96	
	9.28		2.80	
	17.50		13.15	
	5.16		5.53	
	6.09		7.07	
	10.25		5.71	
	9.80		8.39	
$\bar{X}$	12.710	10.144	7.372	10.655
p(t)	.462		.142	

TABLE XVII

NOREPI PRE COMPARISONS: 2-2-1

	2-2-1 DAY PRE	2-2-1 EVE PRE	2-2-1 DAY PRE	2-2-1 MID PRE	2-2-1 EVE PRE	2-2-1 MID PRE
	4.58	3.07	4.58	3.67	3.07	3.67
	9.64	8.90	5.51	4.79	11.64	4.79
	5.51	11.64	6.01	5.12	15.76	5.12
	6.01	15.76	10.46	25.13	6.59	25.13
	3.71	5.65	5.11	3.17	3.48	3.17
	6.69	8.17	11.60	20.78	6.69	20.78
	10.46	6.59	5.68	4.26	4.61	4.26
	7.56	5.84	7.53	2.73	12.87	2.73
	5.11	3.48	8.76	23.37	10.24	23.37
	11.60	6.69	2.27	7.15	2.81	7.15
	5.68	4.61				
	7.53	12.87				
	8.76	10.24				
	6.38	5.12				
	6.97	14.10				
	2.57	2.63				
	2.44	6.16				
	3.90	6.22				
	2.27	2.81				
$\bar{X}$	6.180	7.390	6.751	10.017	7.776	10.017
S.E.	.614	.895	.898	2.897	1.448	2.897
p(t)	.180		.183		.507	

TABLE XVIII

NOREPI POST COMPARISONS: 2-2-1

	2-2-1 DAY POST	2-2-1 EVE POST	2-2-1 DAY POST	2-2-1 MID POST	2-2-1 EVE POST	2-2-1 MID POST
	4.09	2.84	4.09	1.55	2.84	1.55
	26.38	12.47	15.71	7.07	7.58	7.07
	15.71	7.58	14.19	12.28	14.38	12.28
	14.19	14.38	8.58	1.75	5.42	1.75
	7.81	5.84	3.93	3.94	4.47	3.94
	15.19	10.15	47.07	7.44	9.79	7.44
	8.58	5.42	13.80	7.15	7.40	7.15
	6.20	4.49	10.35	9.16	4.62	9.16
	3.93	4.47	10.11	18.61	7.96	18.61
	47.07	9.79	9.80	26.07	8.39	26.07
	13.80	7.40				
	10.35	4.62				
	10.11	7.96				
	9.28	2.80				
	17.50	13.15				
	5.16	5.53				
	6.09	7.07				
	10.25	5.71				
	9.80	8.39				
$\bar{X}$	12.710	7.372	13.763	9.502	7.285	9.502
S.E.	2.283	.768	3.903	2.439	1.036	2.439
p(t)	.014		.378		.333	

TABLE XIX

Comparison of Various ATC Facilities by Means of a Stress Index

Facility	C_s	C_{st}	C_e	C_{ne}
Miami IFSS ('82)*	2.60	.95	1.03	5.85
O'Hare ATCT ('68)	1.05	1.41	.75	.98
Opa Locka ATCT ('72)	.84	.64	.74	1.15
Atlanta ARTCC ('73)	.82	.76	.34	1.37
Miami ARTCC ('72)	.76	.61	.71	.96
Los Angeles TRACON ('74)	.75	.27	1.10	1.44
Houston ATCT ('70)	.74	1.27	.29	.65
Oakland TRACON ('74)	.72	.23	1.31	.61
Houston ATCT ('71)	.68	.89	.62	.52
Oakland TRACON ('72)	.60	.62	.76	.43
Los Angeles TRACON ('72)	.60	.66	.34	.81
Fort Worth ARTCC ('73)	.34	.22	.58	.20

* NOTE: The C_s for Miami IFSS was subsequently corrected as per the Addendum (pages 29 and 30) to 1.46.

TABLE XX

Comparison of Stress Indicator

Hormone Excretion (microgram/100 mg creatinine) at ATC Facilities

Facility	E: Rest	E: Work	NE: Rest	NE: Work	17-KGS: Rest	17-KGS: Work
O'Hare ATCT	.86	1.19	1.86	3.56	---	---
Houston ATCT	.41	1.48	2.31	3.42	100.00	171.19
Los Angeles ATCT	.38	1.19	2.07	4.26	521.30	1152.50
Oakland ATCT	.39	1.25	1.59	2.58	485.10	899.20
Fayetteville ATCT	.53	.86	1.97	2.14	555.70	807.90
Roswell ATCT	.66	1.03	2.26	2.60	526.40	829.00
Oklahoma City FSS	.56	1.17	2.29	3.37	423.10	713.00
Fayetteville FSS	.57	1.05	2.10	2.52	414.70	608.30
Roswell FSS	.66	1.03	2.26	2.60	526.40	829.00
Miami IFSS	.88	1.68	7.69	10.08	824.60	1016.00
Miami IFSS *	.59	1.12	5.33	7.40	593.80	800.60

* NOTE: Subsequent to the above analysis, Miami IFSS data were corrected as per the Addendum (pages 29 and 30).

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Addendum

Since completion of the foregoing report, further laboratory work has pinpointed the cause of the perplexingly high values for the urinary stress indicator hormones (SIH's).

When the urine specimens were received at the Civil Aeromedical Institute from the data collection site they were divided into two parts; one was acidified for catecholamine analysis and the other was used "as is" for adrenal steroid analysis. The Hormonal values were then made relative to 100 mg creatinine. It is now believed that, by human error, samples for creatinine analysis were taken from the nonacidified moiety, resulting in low creatinine values. Because the weight of creatinine forms the denominator of the creatinine-based ratio, calculated SIH's were inordinately high. The fact that all SIH values were high impelled us to look first at the creatinine analysis, but the samples for the reruns were again taken from the urine previously set aside for creatinine analysis, thus giving the same result as the first run. It was only when we started from "square one" that we realized what had happened.

Because the error is a relatively constant one, we do not believe that conclusions regarding differences in the two shift patterns are compromised. The computed level of stress is changed, however, to about half the value reported. The Miami International Flight Service Station (MIA IFSS), though, still retains its number one position on the stress index list, surpassing even O'Hare Tower during the high-stress time of the 1968 ATC slowdown (IFSS Cs= 1.46, ORD Cs= 1.05). The MIA IFSS is high on the stress index list solely because of the inordinately high NE values. The reason for this high level of excretion of the sympathetic nerve transmitter in the MIA IFSS population is still unknown. The indexes for adrenal steroids (Cst) and for epinephrine (Ce) are nominal. Physical exercise is known to increase NE output*; however, the subjects at MIA IFSS as a group were not heavily into exercise, though some individuals worked out regularly. Work in the facility did not seem to be mainly physical; rather, it appeared to be a relatively sedentary occupation.

The general conclusion, based on these new data (page 30), would be that MIA IFSS workers do not show a high level of chronic stress as indicated by adrenal steroid excretion nor do they show a response to a heavy acute workload in their urinary excretion of epinephrine.

The FCL data, of course, are not affected by this biochemical reappraisal.

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TABLE XXI

Revised Mean Values for SIH's - microgram/100 mg Creatinine

E: Rest	E: Work	NE: Rest	NE: Work	KGS: Rest	KGS: Work
.59	1.12	5.33	7.40	593.80	800.60

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